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## MINICOMPUTER-BASED INTERACTIVE IMAGE PROCESSING\*

by

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### ABSTRACT

The Los Alamos Scientific Laboratory is developing a minicomputer-based system for interactive image processing and interactive reduction of data from photographs, radiographs, and other image-like information. This system, Digital Image Analysis and Display System (DIADS), represents an efficient alternative to existing supercomputer-based image processing for most problems. DIADS consists of two linked minicomputers with conventional computer peripherals, special tricolor image processing hardware, and extensive supporting software for handling large arrays of data. DIADS is described and examples of image processing and image analysis results are shown.

### I. INTRODUCTION

The Digital Image Analysis and Display System (DIADS) of the Los Alamos Scientific Laboratory is a minicomputer-based system for interactive image processing and interactive reduction of data from photographs, radiographs, and other image-like information. This facility is being developed to augment the batch image processing done on LASL's large scale scientific computers (7600, CRAY-1). Since interactive image processing requires massive computations and high data transfer rates, such facilities have been realized with very large scale computers or by building special hardware. However, these approaches are either expensive or oriented toward limited specific problems. A third approach is to use a network of mini- and/or microcomputers. This approach is considerably more cost effective and more flexible in the dynamic environment of a research laboratory. The modularity of this approach made it feasible for DIADS to be assembled in piecemeal fashion over several years. In addition to economic expediency and flexibility, this approach enabled us to exploit the rapid growth of mini-microcomputer technology.

Image processing tasks entail the manipulation of large two-dimensional arrays of data. A typical image is composed of 512 by 512 picture elements

or pixels. Some satellite images are thirty times larger in each of four spectral bands. Both the large size and two-dimensional organization of the data complicate image processing. For example, digital filtering an image involves taking the Fourier transform of each row in the image, transposing the result, and taking the Fourier transform of the new rows. Each element of the two-dimensional Fourier transform is then multiplied by the appropriate filter value, and the inverse Fourier transform of the result is computed. For images which are too large to fit into the computer's central memory, the transpose requires several passes through the image.[1] With the FFT algorithm, digitally filtering an  $n \times n$  image takes on the order of  $n^2 \log n$  computations.[2] The massive computation together with the I/O required in the multiple passes of the data through the computer make interactive image processing difficult to achieve.

With DIADS we not only wanted to provide an interactive capability but also wanted to integrate diverse image processing services in one facility. These services include digitizing film, displaying and processing digitized images, data analysis and reduction, producing hard copy of digitized images, and providing a software development environment for image analysts with varying programming skills. These services are based on special purpose peripheral devices which invariably dominate a minicomputer. Therefore, a distributed system of processors is the only viable way to combine integration of services with interactive performance levels. Image processing tasks are distributed between the minicomputer CPU's and special purpose peripherals with hardware or microcomputer based processing capabilities. This arrangement places the least demand on the network links and was consistent with the gradual development of DIADS.

### II. EQUIPMENT

Figure 1 shows the equipment configuration of DIADS in the fall of 1979. The main DIADS computer is a PDP 11/55 with floating point and 96K words of memory of which one half is high speed. The DIADS support computer is a PDP 11/40 with 88K words of memory. The two computers are linked with a DEC DMC 11 network link which is described in detail elsewhere in these proceedings.[3] Mass storage for the image data base is supplied by two

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176-Megabyte disks. Eleven office terminals share six ports to the main computer.

Image digitization is available through the Spatial Data Systems Computer Eye which is connected to the support computer. This video scanner provides a quick but limited digitization. The image size is 512 by 512 pixels with 8 bits of precision per sample. The device operates under the control of the support computer and generates one interrupt per sample or 262,144 per image.

DIADS has two full color image display systems connected to the main computer. Each system can store four 512 by 512 by 8 bit images in its own memory. The systems are both manufactured by COMTAL. The newer system, Vision One/20, uses firmware and new technology to extend the hardware of the older, 8000-S system.

The older display system has four table look-up memories for function processing, a pseudo-color table look-up memory, real time multispectral data classifier and pixel counter, and four graphics overlay memories. This system is operated through a standard CRT terminal that is independently connected to the host computer. The hardware processors reduce the number of image transfers from the host computer to the device for certain applications. However, all user interaction and calculation of tables is done by the host. The image memories are only block addressable in the manner of a disk unit. Thus, the host computer may access rows of the image but not columns.

The newer display system has an LSI microprocessor with its own operating system which controls user interaction via keyboard, track ball, or digital tablet. The hardware processors have been expanded to include image arithmetic combination and convolution as well as table look-up processing. The image memory is random access, expandable to 4096 by 4096 pixels, and managed by the microprocessor. The monitor can display a 512 by 512 portion of the image memory. The system processors permit roam and zoom by the operator. Once the image memories are loaded, the system can perform many applications without interrupting the host computer.

The array processor is a Floating Point Systems AP-120B with 64K words of main data memory at 38 bits per word and 3K of program source memory at 64 bits per word. This device is specially designed to perform high-speed arithmetic operations on large arrays of numbers. For certain applications such as digital filtering, the array processor produces computations at a rate comparable to a large-scale scientific computer. The 64K words of memory on DIADS array processor holds a 256 by 256 image throughout a sequence of operations. For larger images the host computer is heavily involved in transferring data to and from the array processor.

### III. SOFTWARE

The distribution of image processing services among processors meant that software had to be

correspondingly distributed. The feature that unifies DIADS is the convenient transfer of images throughout the facility. Thus, the glue that holds the software components together is the image data structure. DIADS main software goal of user convenience was met by integrating the design characteristics even though the software is distributed.

The UNIX Time-Sharing System was selected for both the main and the support computers. UNIX is a general-purpose, multi-user, interactive operating system which offers features usually associated with very large operating systems. New users have found UNIX easy to learn. The ability to initiate asynchronous processes and the compatibility of file, device, and interprocess I/O have facilitated software distribution. Components may be executed on the same processor or different processors. Thus, reconfiguring DIADS' equipment for near term expediency is easy. The hierarchical file system is the foundation for the image data base. For certain image processing tasks it has been necessary to bypass the UNIX file system and use basic disk operations. These situations occur when the peripheral device processor is overly dependent on the host computer.

All software components are divided into three levels. The bottom level subroutines contain all peripheral device operations. The top level pertains to user interaction. The image processing subroutines at the middle level are device independent and do not require user interaction. Thus, image processing libraries are shared among the components and the user interface is kept consistent throughout DIADS.

The image data structure (IDS) unifies the digitization, computation, and display aspects of image processing. The representation of the picture elements is different for each use. An 8-bit binary representation is used for display and a floating point representation is used for digital filtering. All of the representations are supported by the IDS. In addition, information relevant to each use of the image is stored in the IDS. Image statistics are important to computation. Function tables, pseudocolor tables, and graphics overlays are necessary to recreate a visual presentation. These items and many others may be stored in the IDS. The image representation is converted, if necessary, as the data is transferred from the data base to a software component. Thus, each component works with one representation.

### IV. EXAMPLES

DIADS serves three major functions for its users:

1. Display of output from processing on other computers.
2. Interactive image processing.
3. Interactive mensuration of image data.

The first function demands very little of the minicomputer system. Images are read from disk or

tape one line at a time and transferred to the refresh memory of one of the TV image display systems. As simple as this is, this function accounts for the greatest number of user contacts with DIADS. This function is required because of the numbers of image processing tasks that are too large for the minicomputer system or which use computer programs which existed before DIADS. Examples of such problems are: (1) computed tomography research and simulation; (2) iterative or nonlinear image restoration; and (3) simulation of images involving complex physical phenomena.

The second function combines the hardware features of the TV image processing systems and control programs which run on the PDP-11 minicomputers the array processor.

One example of the former type of enhancement is interactive contrast stretching. In this enhancement software on the PDP-11 interprets x-y coordinate data from the trackball movement on the display system and constructs a mapping of the 256 input gray levels into up to 256 output gray levels. The mapping is an array of 256 8-bit integers which is written to a special "function" memory in the display system. The user feels that the interactive enhancement is essentially instantaneous; as the trackball moves the contrast of the displayed image changes. Figure 2 shows how the x-y position of the cursor on the image display screen is interpreted to set the breakpoints in a piecewise linear stretching function. Many other interactive stretching schemes are available. Figure 3 shows the results of a simple function memory enhancement of a dental x ray.

Figure 4 shows the results of a simple convolutional enhancement of a 512 x 512 dental x ray. First, the image is blurred by convolving with a square Fourier window. Then the blurred image is added to the original with weights of -3 and 4, respectively. This process (sometimes called unsharp masking) tends to remove large scale variations in the image and enhance edges.

The third function of DIADS is image mensuration. Scientific images are rarely of value in themselves; rather, they are useful for the data they contain. The ultimate goal of image processing is to render the data more useful. Much information is extracted from an image by measuring the size and/or location of features in the image. Other information can be obtained from the photographic densities (gray levels) in an image. Mensuration can be either fully computer controlled or interactive. In interactive mensuration a human analyst either obtains the raw data or guides the computer in extracting it; the computer then reduces the information. The interactive approach has been found to be most cost-effective at LASL.

Figure 5 shows the final TV display after an interactive mensuration task. The input image was a stop motion radiograph of a high speed pellet which is assumed to be built up of some number of figures of revolution. The radiograph was digitized and enhanced. A PDP 11/55 program was written to interact with an analyst and the 8000 COMTAL.

The operator uses the trackball as an x-y comparator and selects the axis of revolution followed by an arbitrary number of points on the perimeter of the object. The program then calculates the volume of the object using simple geometry. The operator is presented with the results and then offered the chance to reposition his data points if some seem bad after the first iteration. Because of the noise in this image, which is typical of flash radiography, automatic edge following was not possible.

These have been a limited number of examples of image enhancement and mensuration on DIADS. As DIADS hardware and software continue to grow, so do the capabilities of the system. It is expected that, based on experience in the general purpose system, other, more specialized systems can be built to do specific, high volume tasks as the need arises.

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- [2] Harry C. Andrews, Computer Techniques in Image Processing, Academic Press, New York 1970, Chapter 5.
- [3] Sherron L. Green and S. T. Alexander, "Implementation and Performance of a UNIX Link," these proceedings.

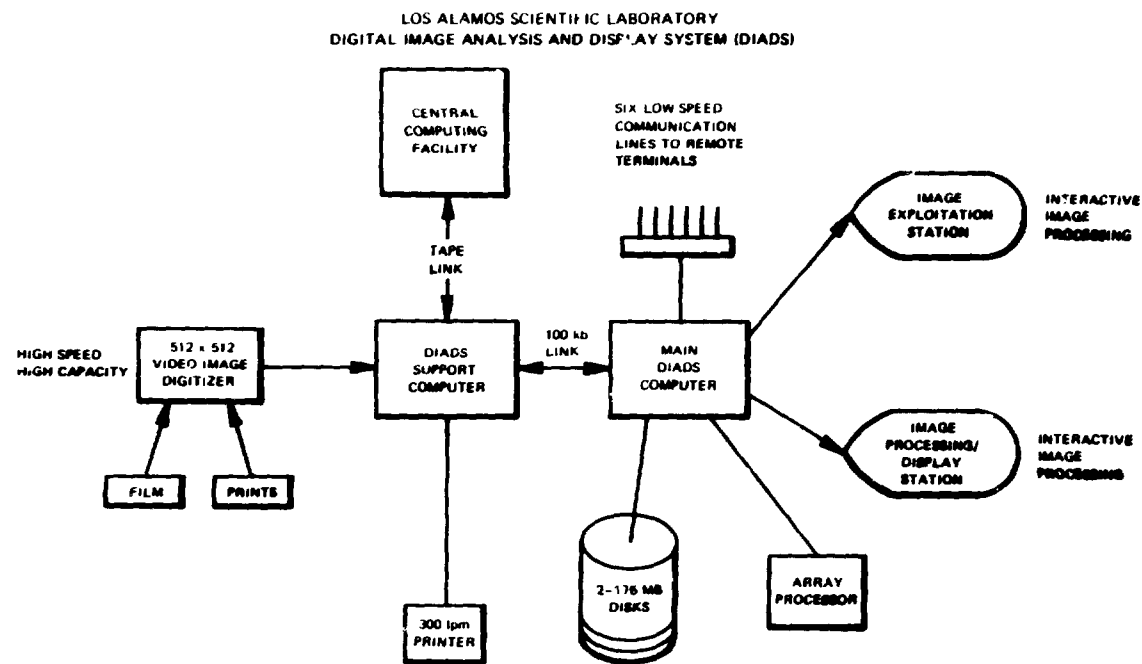


Fig. 1. DIADS Configuration, Fall, 1979

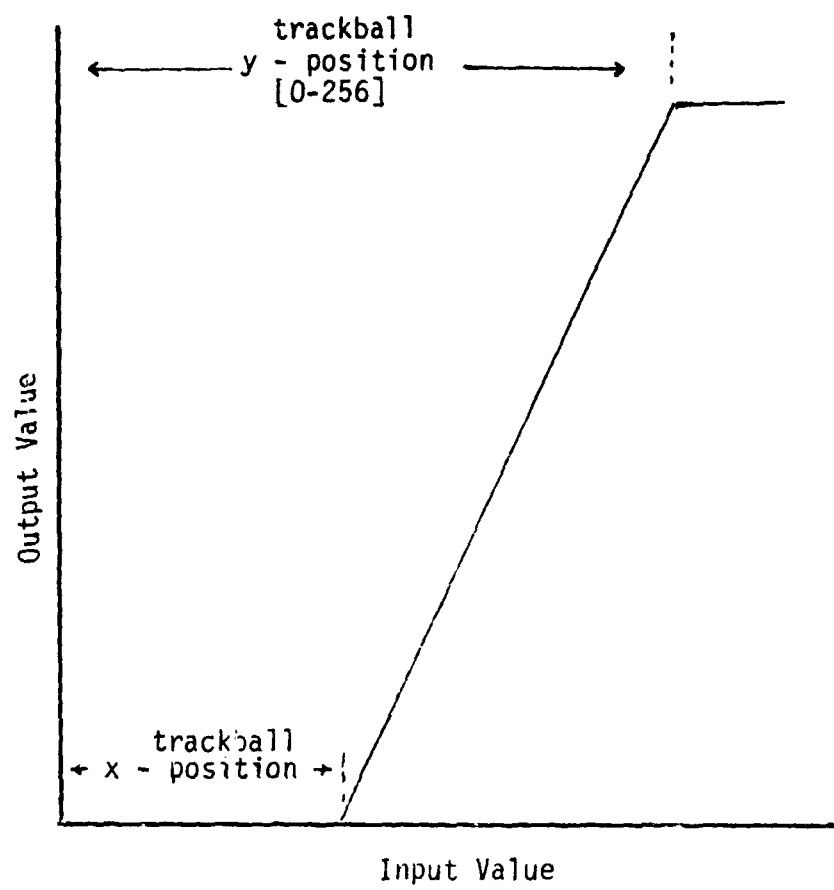


Fig. 2 Interactive image enhancement  
using a trackball to set two  
parameters on a stretching  
function



Fig. 3 Function Memory Enhancement on DIADS



Fig. 4 Convolutional Enhancement on DIADS

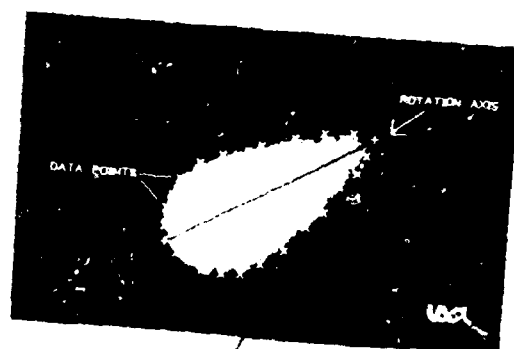


Fig. 5. Final Results of Interactive  
Mensuration on DIADS